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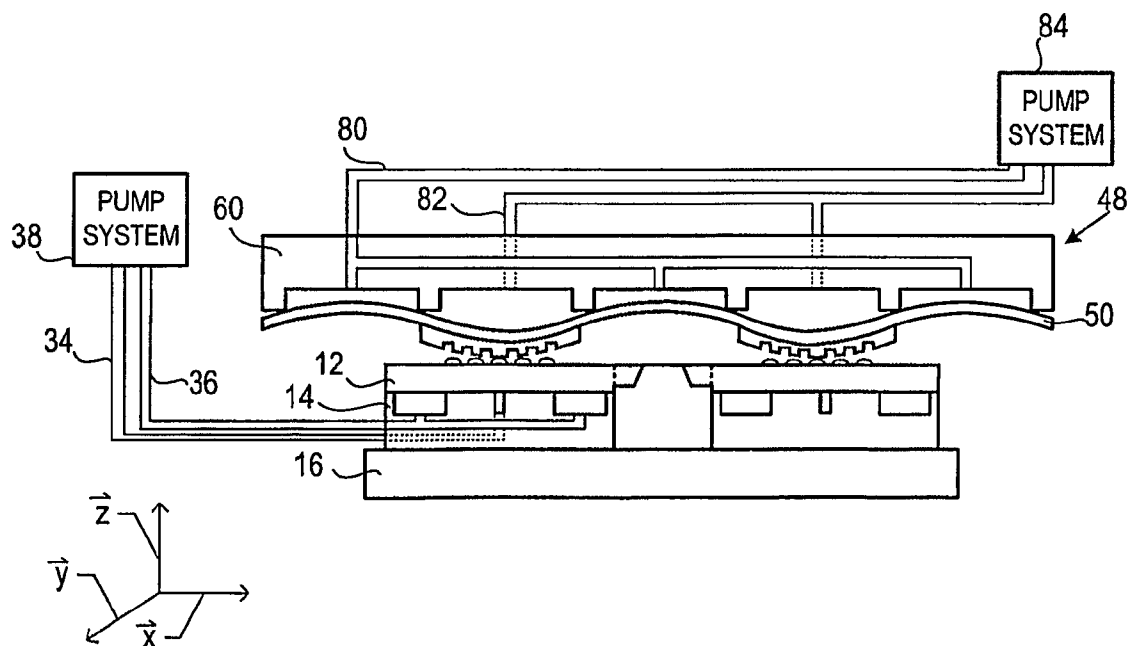
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(54) Title: METHOD FOR EXPELLING GAS POSITIONED BETWEEN A SUBSTRATE AND A MOLD



(57) Abstract: The present invention is directed towards a method of expelling a gas positioned between a substrate and a mold, the substrate and the mold further having a liquid positioned therebetween.

METHOD FOR EXPELLING GAS POSITIONED BETWEEN A SUBSTRATE AND A MOLD

[0001] Nano-fabrication involves the fabrication of very small structures, e.g.,
5 having features on the order of nanometers or smaller. One area in which nano-fabrication has had a sizeable impact is in the processing of integrated circuits. As the semiconductor processing industry continues to strive for larger production yields while increasing the circuits per unit area formed on a substrate, nano-fabrication becomes increasingly important. Nano-fabrication provides greater process control
10 while allowing increased reduction of the minimum feature dimension of the structures formed. Other areas of development in which nano-fabrication has been employed include biotechnology, optical technology, mechanical systems and the like.

[0002] An exemplary nano-fabrication technique is commonly referred to as
15 imprint lithography. Exemplary imprint lithography processes are described in detail in numerous publications, such as United States patent application publication 2004/0065976 filed as United States patent application 10/264,960, entitled, "Method and a Mold to Arrange Features on a Substrate to Replicate Features having Minimal Dimensional Variability;" United States patent application publication 2004/0065252
20 filed as United States patent application 10/264,926, entitled "Method of Forming a Layer on a Substrate to Facilitate Fabrication of Metrology Standards;" and United States patent number 6,936,194, entitled "Functional Patterning Material for Imprint Lithography Processes," all of which are assigned to the assignee of the present invention.

25 [0003] The fundamental imprint lithography technique disclosed in each of the aforementioned United States patent application publications and United States patent includes formation of a relief pattern in a polymerizable layer and transferring a pattern corresponding to the relief pattern into an underlying substrate. The substrate may be positioned upon a motion stage to obtain a desired position to
30 facilitate patterning thereof. To that end, a template is employed spaced-apart from the substrate with a formable liquid present between the template and the substrate. The liquid is solidified to form a solidified layer that has a pattern recorded therein

that is conforming to a shape of the surface of the template in contact with the liquid. The template is then separated from the solidified layer such that the template and the substrate are spaced-apart. The substrate and the solidified layer are then subjected to processes to transfer, into the substrate, a relief image that corresponds to the pattern
5 in the solidified layer.

[0004] To that end, gases may be present between the template and the substrate and within the formable liquid which may result in, *inter alia*, pattern distortion of the solidified layer, low fidelity of features formed in the solidified layer, and a non-uniform thickness of a residual layer of the solidified layer, all of which are
10 undesirable. To that end, a need exists, therefore, to provide a method and a system to expel gas positioned between a substrate and a mold. Embodiments of the invention are now described with reference to the drawings in which:

[0005] Fig. 1 is a simplified side view of a lithographic system having a
15 patterning device spaced-apart from a substrate, the patterning device comprising a template and a mold;

[0006] Fig. 2 is a top down view of the substrate shown in Fig. 1, the substrate having an inner, middle, and outer radius;

[0007] Fig. 3 is a side view of the substrate shown in Fig. 1 coupled to a
20 substrate chuck;

[0008] Fig. 4 is a bottom-up plan view of the substrate chuck shown in Fig. 3

[0009] Fig. 5 is a top down view of the template shown in Fig 1, having a mold coupled thereto;

[0010] Fig. 6 is a side view of the template shown in Fig. 1 coupled to a
25 template chuck;

[0011] Fig. 7 is a bottom-up plan view of the template chuck shown in Fig. 6;

[0012] Fig. 8 is a top down view showing an array of droplets of imprinting material positioned upon a region of the substrate shown in Fig. 1;

[0013] Fig. 9 is a simplified side view of the substrate shown in Fig. 1, having
30 a patterned layer positioned thereon;

[0014] Fig. 10 is a flow diagram showing a method of patterning the substrate shown in Fig. 1, in a first embodiment;

[0015] Fig. 11 is a side view of the patterning device shown in Fig. 1 having an altered shape;

[0016] Fig. 12 is a side view of the patterning device shown in Fig. 11, in contact with a portion of the droplets of imprinting material shown in Fig. 8;

5 [0017] Figs. 13-15 are top down views showing the compression of the droplets shown in Fig. 8, employing the altered shape of the template shown in Fig. 12;

[0018] Fig. 16 is a flow diagram showing a method of patterning a region of the substrate shown in Fig. 1, in a second embodiment;

10 [0019] Fig. 17 is a side view of the substrate shown in Fig. 1 having an altered shape;

[0020] Fig. 18 is a side view of a pin exerting a force on the patterning device shown in Fig. 1, to alter a shape thereof; and

[0021] Fig. 19 is a side view of the system shown in Fig. 1, with a gas being
15 introduced between the patterning device and the mold.

[0022] Referring to Figs. 1 and 2, a system 10 to form a relief pattern on a substrate 12 is shown. Substrate 12 may have circular shape; however, in a further embodiment, substrate 12 may have any geometric shape. In the present example,
20 substrate 12 may have a disk shape having an inner radius r_1 and outer radius r_2 , with radius r_2 being greater than radius r_1 . Further, defined between inner radius r_1 and outer radius r_2 is a middle radius r_3 , with middle radius r_3 positioned substantially equidistant from inner radius r_1 and outer radius r_2 .

[0023] Referring to Fig. 1, substrate 12 may be coupled to a substrate chuck
25 14. As shown substrate chuck 14 is a vacuum chuck, however, substrate chuck 14 may be any chuck including, but not limited to, vacuum, pin-type, groove-type, or electromagnetic, as described in United States patent 6,873,087 entitled "High-Precision Orientation Alignment and Gap Control Stages for Imprint Lithography Processes," which is incorporated herein by reference. Substrate 12 and substrate
30 chuck 14 may be supported upon a stage 16. Further, substrate 12, substrate chuck 14, and stage 16 may be positioned on a base (not shown). Stage 16 may provide motion about a first and a second axis, with the first and the second axis being orthogonal to one another, i.e., the x and y axes.

[0024] Referring to Figs. 1, 3, and 4, substrate chuck 14 includes first 18 and second 20 opposed sides. A side, or edge, surface 22 extends between first side 18 and second side 20. First side 18 includes a first recess 20, a second recess 22, and a third recess 24, defining first 26, second 28, third 30, and fourth 32 spaced-apart support regions. First support region 26 cinctures second 28, third 30, and fourth 32 support regions and first 20, second 22, and third 24 recesses. Second support region 28 cinctures third 30 and fourth 32 support regions and second 22 and third 24 recesses. Third support region 30 cinctures fourth support region 32 and third recess 24. Third recess 24 cinctures fourth support region 32. In a further embodiment, first 26, second 28, third 30, and fourth 32 support regions may be formed from a compliant material. First 26, second 28, third 30, and fourth 32 support regions may have a circular shape; however, in a further embodiment, first 26, second 28, third 30, and fourth 32 may comprise any geometric shape desired.

[0025] Formed in substrate chuck 14 are throughways 34 and 36, however, substrate chuck 12 may comprise any number of throughways. Throughway 34 places first and third recesses 20 and 24 in fluid communication with side surface 18, however, in a further embodiment, it should be understood that throughway 34 may place first and third recesses 20 and 24 in fluid communication with any surface of substrate chuck 14. Throughway 36 places second recess 22 in fluid communication with side surface 18, however, in a further embodiment, it should be understood that throughway 36 may place second recess 22 in fluid communication with any surface of substrate chuck 14. Furthermore, what is desired is that throughway 34 facilitates placing first 20 and third 24 recesses and throughway 36 facilitates placing second recesses 22 in fluid communication with a pressure control system, such as a pump system 38.

[0026] Pump system 38 may include one or more pumps to control the pressure proximate to first 20, second 22, and third 24 recesses. To that end, when substrate 12 is coupled to substrate chuck 14, substrate 12 rests against first 26, second 28, third 30, and fourth 32 support regions, covering first 20, second 22, and third 24 recesses. First recess 20 and a portion 40a of substrate 12 in superimposition therewith define a first chamber 42. Second recess 22 and a portion 40b of substrate 12 in superimposition therewith define a second chamber 44. Third recesses 24 and a portion 40c of substrate 12 in superimposition therewith define a third chamber 46.

Pump system 38 operates to control a pressure in first 42, second 44, and third 46 chambers.

[0027] Referring to Figs. 1 and 5, spaced-apart from substrate 12 is a patterning device 48. Patterning device 48 comprises a template 50 having a mesa 52 extending therefrom towards substrate 12 with a patterning surface 54 thereon. Further, mesa 52 may be referred to as a mold 52. In a further embodiment, template 50 may be substantially absent of mold 52. Template 50 and/or mold 52 may be formed from such materials including but not limited to, fused-silica, quartz, silicon, organic polymers, siloxane polymers, borosilicate glass, fluorocarbon polymers, metal, and hardened sapphire. As shown, patterning surface 54 comprises features defined by a plurality of spaced-apart recesses 56 and protrusions 58. However, in a further embodiment, patterning surface 54 may be substantially smooth and/or planar. Patterning surface 54 may define an original pattern that forms the basis of a pattern to be formed on substrate 12.

[0028] Referring to Figs. 1, 6, and 7, template 50 may be coupled to a template chuck 60, template chuck 60 being any chuck including, but not limited to, vacuum, pin-type, groove-type, or electromagnetic, as described in United States patent 6,873,087 entitled "High-Precision Orientation Alignment and Gap Control Stages for Imprint Lithography Processes". Template chuck 60 includes first 62 and second 64 opposed sides. A side, or edge, surface 66 extends between first side 62 and second side 64. First side 62 includes a first recess 68, a second recess 70, and a third recess 72, defining first 74, second 76, and third 78 spaced-apart support regions. First support region 74 cinctures second 70 and third 72 support regions and first 68, second 70, and third 72 recesses. Second support region 76 cinctures third support region 78 and second 70 and third 72 recesses. Third support region 78 cinctures third recess 72. In a further embodiment, first 74, second 76, and third 78 support regions may be formed from a compliant material. First 74, second 76, and third 78 support regions may have a circular shape; however, in a further embodiment, first 74, second 76, and third 78 support regions may have any geometric shape desired.

[0029] Formed in template chuck 60 are throughways 80 and 82, however, template chuck 60 may comprise any number of throughways. Throughway 80 places first and third recesses 68 and 72 in fluid communication with second side 64,

however, in a further embodiment, it should be understood that throughway 80 may place first and third recesses 68 and 72 in fluid communication with any surface of template chuck 60. Throughway 82 places second recess 70 in fluid communication with second side 64, however, in a further embodiment, it should be understood that
5 throughway 80 may place second recess 70 in fluid communication with any surface of template chuck 60. Furthermore, what is desired is that throughway 80 facilitates placing first 68 and third 72 recesses and throughway 82 facilitates placing second recesses 70 in fluid communication with a pressure control system, such as a pump system 84.

10 **[0030]** Pump system 84 may include one or more pumps to control the pressure proximate to first 68, second 70, and third 72 recesses. To that end, when template 50 is coupled to template chuck 60, template 50 rests against first 74, second 76, and third 78 support regions, covering first 68, second 70, and third 72 recesses. First recess 68 and a portion 86a of template 50 in superimposition therewith define a
15 first chamber 88. Second recess 70 and a portion 86b of template 50 in superimposition therewith define a second chamber 92. Third recess 72 and a portion 86c of substrate 12 in superimposition therewith define a third chamber 96. Pump system 84 operates to control a pressure in first 88, second 92, and third 96 chambers. Further, template chuck 60 may be coupled to an imprint head 97 to facilitate
20 movement of patterning device 48.

[0031] Referring to Fig. 1, system 10 further comprises a fluid dispense system 98. Fluid dispense system 98 may be in fluid communication with substrate 12 so as to deposit polymeric material 100 thereon. Fluid dispense system 98 may comprise a plurality of dispensing units therein. It should be understood that
25 polymeric material 100 may be deposited using any known technique, e.g., drop dispense, spin-coating, dip coating, chemical vapor deposition (CVD), physical vapor deposition (PVD), thin film deposition, thick film deposition, and the like. Typically, polymeric material 100 may be disposed upon substrate 12 before the desired volume is defined between mold 52 and substrate 12. However, polymeric material 100 may
30 fill the volume after the desired volume has been obtained. As shown in Fig. 8, polymeric material 100 may be deposited upon substrate 12 as a plurality of spaced-apart droplets 102, defining a matrix array 104. In an example, each droplet of

droplets 102 may have a unit volume of approximately 1-10 pico-liters. Droplets 102 may be arranged in any two-dimensional arrangement on substrate 12.

[0032] Referring to Figs. 1 and 9, system 10 further comprises a source 106 of energy 108 coupled to direct energy 108 along a path 110. Imprint head 97 and stage 16 are configured to arrange mold 52 and substrate 12, respectively, to be in superimposition and disposed in path 110. Either imprint head 97, stage 16, or both vary a distance between mold 52 and substrate 12 to define a desired volume therebetween that is filled by polymeric material 100. After the desired volume is filled with polymeric material 100, source 106 produces energy 108, e.g., broadband ultraviolet radiation that causes polymeric material 100 to solidify and/or cross-link conforming to the shape of a surface 112 of substrate 12 and patterning surface 54, defining a patterned layer 114 on substrate 12. Patterned layer 114 may comprise a residual layer 116 and a plurality of features shown as protrusions 118 and recessions 120. Control of this process is regulated by a processor 122 that is in data communication with stage 16, pump systems 38 and 84, imprint head 97, fluid dispense system 98, and source 106, operating on a computer readable program stored in a memory 124.

[0033] Referring to Fig. 1, system 10 further includes a pin 126 coupled to stage 16. Pin 126 may translate about a third axis orthogonal to the first and second axis, i.e., along the z axis. As a result, pin 126 may contact mold 52 to alter a shape thereof, described further below. Pin 126 may be any force or displacement actuator known in the art including, *inter alia*, pneumatic, piezoelectric, magnetostrictive, linear, and voice coils. In a further embodiment, pin 126 may be a high resolution pressure regulator and clean series air piston, with a center pin thereof comprising a vacuum source that may evacuate an atmosphere between an interface of patterning device 48 and substrate 12.

[0034] Referring to Figs. 1, 8, and 9, as mentioned above, a distance between mold 52 and substrate 12 is varied such that a desired volume is defined therebetween that is filled by polymeric material 100. Furthermore, after solidification, polymeric material 100 conforms to the shape of surface 112 of substrate 12 and patterning surface 54, defining patterned layer 114 on substrate 12. To that end, in a volume 128 defined between droplets 102 of matrix array 104, there are gases present, and droplets 102 in matrix array 104 are spread over substrate 12 so as to avoid, if not

prevent, trapping of gases and/or gas pockets between substrate 12 and mold 52 and within patterned layer 114. The gases and/or gas pockets may be such gases including, but not limited to air, nitrogen, carbon dioxide, and helium. Gas and/or gas pockets between substrate 12 and mold 52 and within patterned layer 114 may result in, *inter alia*, pattern distortion of features formed in patterned layer 114, low fidelity of features formed in patterned layer 114, and a non-uniform thickness of residual layer 116 across patterned layer 114, all of which are undesirable. To that end, a method and a system of minimizing, if not preventing, trapping of gas and/or gas pockets between substrate 12 and mold 52 and within patterned layer 114 are described below.

[0035] Referring to Figs. 1 and 10, in a first embodiment, a method of expelling gas between substrate 12 and mold 52 is shown. More specifically, at step 200, as mentioned above, polymeric material 100 may be positioned on substrate 12 by drop dispense, spin-coating, dip coating, chemical vapor deposition (CVD), physical vapor deposition (PVD), thin film deposition, thick film deposition, and the like. In a further embodiment, polymeric material 100 may be positioned on mold 52.

[0036] Referring to Figs. 6, 7, 10, and 11, at step 202, a shape of patterning device 48 may be altered. More specifically, a shape of patterning device 48 may be altered such that a distance d_1 defined between mold 52 and substrate 12 at middle radius r_3 of substrate 12, shown in Fig. 2, is less than a distance defined between mold 52 and substrate 12 at remaining portions of mold 52. In an example, distance d_1 is less than a distance d_2 , distance d_2 being defined at an edge of mold 52. In a further embodiment, the distance d_1 may be defined at any desired location of mold 52. The shape of patterning device 48 may be altered by controlling a pressure within first and third chambers 68 and 72. More specifically, as mentioned above, pump system 84 operates to control the pressure in first and third chambers 68 and 72. To that end, pump system 84 may create a vacuum within first and third chambers 68 and 72 via throughway 80 such that portions 86a and 86c of template 50 may bow away from substrate 12 and bow towards template chuck 60. As a result of bowing portions 86a and 86c of template 50 away from substrate 12, portion 86b of template 50 bows toward substrate 12 and away from template chuck 60.

[0037] Referring to Figs. 10, 12, and 13, at step 204, as described above with respect to Fig. 1, either imprint head 97, shown in Fig. 1, stage 16, or both, may vary

distance d_1 , shown in Fig. 11, such that a portion of mold 52 contacts a sub-portion of droplets 102. As shown, a portion of mold 52 in superimposition with middle radius r_3 of substrate 12, shown in Fig. 2, contacts a sub-portion of droplets 102 prior to the remaining portions of mold 52 contacting the remaining droplets of droplets 102.

5 However, in a further embodiment, any portion of mold 52 may contact droplets 102 prior to remaining portions of mold 52. To that end, as shown, mold 52 contacts all of droplets 102 in superimposition with middle radius r_3 of substrate 12, shown in Fig. 2, substantially concurrently. This causes droplets 102 to spread and to produce a contiguous liquid sheet 130 of polymeric material 100. Edge 132 of liquid sheet 130
10 defines a liquid-gas interface 134 that functions to push gases in volume 128 toward edge 136 of substrate 12. Volume 128 between droplets 102 define gas passages through which gas may be pushed to edge 136. As a result, liquid-gas interface 134 in conjunction with the gas passages reduces, if not prevents, trapping of gases in liquid sheet 130.

15 [0038] Referring to Figs. 7, 10, and 14, at step 206, the shape of patterning device 48 may be altered such that the desired volume defined between mold 52 and substrate 12 may be filled by polymeric material 100, as described above with respect to Fig. 1. More specifically, the shape of patterning device 48 may be altered by the combination of controlling the pressure within first and third chambers 88 and 96 and
20 a force exerted by imprint head 97, shown in Fig. 1, and/or stage 16 upon patterning device 48 as a result of contact between polymeric material 100 and mold 52. More specifically, as mentioned above, pump system 84 operates to control the pressure in first and third chambers 88 and 96. To that end, pump system 84 decreases a magnitude of the vacuum created within first and third chambers 88 and 96 via
25 throughway 80 such that polymeric material 100 associated with subsequent subsets of droplets 100 surrounding middle radius r_3 of substrate 12 shown in Fig. 2, spread to become included in contiguous fluid sheet 130, as shown in Fig. 14. The shape of patterning device 48 continues to be altered such that mold 52 subsequently comes into contact with the remaining droplets 102 so that polymeric material 100 associated
30 therewith spreads to become included in contiguous sheet 130, as shown in Fig. 15. As can be seen, interface 134 has moved towards edge 136 so that there is an unimpeded path for the gases in the remaining volume 128, shown in Fig. 8, to travel thereto. This allows gases in volume 128, shown in Fig. 8, to egress from between

mold 52 and substrate 12 vis-à-vis edge 136. In this manner, the trapping of gas and/or gas pockets between substrate 12 and mold 52 and within patterned layer 114, shown in Fig. 9, is minimized, if not prevented. In a further embodiment, the shape of patterning device 48 may be altered concurrently with decreasing the distance d_1 , as mentioned above with respect to Fig. 11.

[0039] Referring to Figs. 7 and 12, in still a further embodiment, to facilitate altering a shape of patterning device 48, a pressure within second chamber 92 may be controlled. More specifically, as mentioned above, pump system 84 operates to control the pressure in second chamber 92. To that end, pump system 84 may create a pressure within second chamber 92 via throughway 82 such that portion 86c of template 50 may bow towards substrate 12 and bow away from template chuck 60. Further, a pressure may be created within second chamber 92 concurrently with creating a vacuum in first and third chamber 88 and 96, as mentioned above.

[0040] Referring to Fig. 1 and 10, at step 208, as mentioned above with respect to Fig. 1, polymeric material 100 may be then be solidified and/or cross-linked, defining patterned layer 114, shown in Fig. 9. Subsequently, at step 210, mold 52 may be separated from patterned layer 114, shown in Fig. 9.

[0041] Referring to Figs. 1 and 16, a further embodiment of the present invention is shown. More specifically, at step 300, analogous to that mentioned above with respect to step 200, shown in Fig. 10, polymeric material 100 may be positioned on substrate 12 or mold 52.

[0042] Referring to Figs. 3, 4, 16, and 17, at step 302, analogous to that mentioned above with respect to step 202, shown in Fig. 10, a shape of patterning device 48 may be altered. Furthermore, concurrently with altering a shape of patterning device 48, a shape of substrate 12 may be altered. More specifically, a shape of substrate 12 may be altered by controlling a pressure within first and third chambers 42 and 46. More specifically, as mentioned above, pump system 38 operates to control the pressure in first and third chambers 42 and 46. To that end, pump system 38 may create a vacuum within first and third chambers 42 and 46 via throughway 36 such that portions 40a and 40c of substrate 12 may bow away from substrate chuck 14 and bow towards mold 52, as shown in Fig. 17. As a result of bowing portions 40a and 40c of substrate 12 toward from substrate chuck 14, portion 40b of substrate 12 bows toward mold 52 and away from substrate chuck 14.

Referring to Figs. 11, 13, and 16, at step 304, analogous to that mentioned above with respect to step 204, shown in Fig. 10, imprint head 97, stage 16, or both, may vary distance d_1 , shown in Fig. 11, such that a portion of mold 52 contacts a sub-portion of droplets 102 in superimposition with middle radius r_3 of substrate 12, shown in Fig. 2, substantially concurrently, producing contiguous liquid sheet 130 of polymeric material 100.

[0043] Referring to Figs. 4, 12, and 16, at step 306, analogous to that mentioned above with respect to step 206, shown in Fig. 10, the shape of patterning device 48 may be altered such that the desired volume defined between mold 52 and substrate 12 may be filled by polymeric material 100. Furthermore, concurrently with altering the shape of patterning device 48, the shape of substrate 12 may be altered. More specifically, as mentioned above, pump system 38 operates to control the pressure in first and third chambers 42 and 26. To that end, pump system 38 decreases a magnitude of the vacuum created within first and third chambers 42 and 46 via throughway 36 concurrently with altering a shape of patterning device 48 as mentioned above in step 204, shown in Fig. 10, such that polymeric material 100 associated with droplets 102 surrounding middle radius r_3 of substrate 12, shown in Fig. 2, spread to become included in contiguous fluid sheet 130, as shown in Fig. 14. The shape of substrate 12 may be further altered concurrently with the shape of patterning device 48 being altered such that mold 52 subsequently comes into contact with the remaining droplets 102 so that polymeric material 100 associated therewith spreads to become included in contiguous sheet 130, as shown in Fig. 15. The gases in volume 128, shown in Fig. 8 may egress from between mold 52 and substrate 12 vis-à-vis edge 136 in substantially the same method as mentioned above with respect to step 206, shown in Fig. 10.

[0044] Referring to Figs. 3 and 4, to further facilitate altering a shape of substrate 12, a pressure within second chamber 44 may be controlled. More specifically, as mentioned above, pump system 38 operates to control the pressure in second chamber 44. To that end, pump system 38 may create a pressure within second chamber 44 via throughway 34 such that portion 40b of template 50 may bow towards mold 52 and bow away from substrate chuck 14. Further, a pressure may be created within second chamber 44 concurrently with creating a vacuum in first and third chamber 42 and 46, as mentioned above.

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[0045] Referring to Fig. 1 and 10, at step 308, as mentioned above with respect to Fig. 1, polymeric material 100 may be then be solidified and/or cross-linked, defining patterned layer 114, shown in Fig. 9. Subsequently, at step 310, mold 52 may be separated from patterned layer 114, shown in Fig. 9.

5 [0046] Referring to Figs. 6 and 18, in a further embodiment, to facilitate altering a shape of patterning device 48, pin 126 may be employed. More specifically, pin 126 may exert a force upon patterning device 48, and in the present example, upon third portion 86c of template 50. As a result, patterning device 48 may comprise the aforementioned desired altered shape and may be employed in any of
10 the methods mentioned above. Pin 126 may be also employed to facilitate separation of mold 52 and substrate 12, as mentioned above with respect to steps 208 and 308, shown in Figs. 10 and 16, respectively. Furthermore, after formation of patterned layer 114, shown in Fig. 9, pin 126 may translate away from patterned device 48 such that patterning device 48 may be substantially flat. Pin 126 may be in communication
15 with processor 122 such that pin 126 may employ force feedback to determine a magnitude of the force.

[0047] Referring to Fig. 19, to further facilitate separation of mold 52 and substrate 12, a gas 148 may be introduced between substrate 12 and mold 52 via pin 126. More specifically, pin 126 may comprise a throughway 150 having apertures
20 152 in fluid communication with a pressure control system, such as a pump system 38. In a further embodiment, pin 126 may comprise any number of apertures. Apertures 152 may be positioned to introduce gas 148 between mold 52 and substrate 12. Gas 148 exerts a force upon mold 52 and substrate 12 to push mold 52 in a direction away from substrate 12 and to push substrate 12 in a direction away from
25 mold 52. As shown, gas 148 may be introduced between mold 52 and substrate 12 when pin 126 is proximate to template 50; however, in a further embodiment, gas 148 may be introduced between mold 52 and substrate 12 when pin 126 is in any position.

[0048] The embodiments of the present invention described above are exemplary. Many changes and modifications may be made to the disclosure recited
30 above, while remaining within the scope of the invention. Therefore, the scope of the invention should not be limited by the above description, but instead should be determined with reference to the appended claims along with their full scope of equivalents.

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CLAIMS

1. A method for expelling a gas positioned between a substrate and a mold assembly, said substrate and said mold assembly further having a liquid positioned therebetween, said method comprising the steps of:

positioning said mold assembly and said substrate such that said mold assembly is proximate to said substrate, said mold assembly having a first region, a second region, and a third region, said second region surrounding said first region and said third region surrounding said first and second regions;

altering a shape of said mold assembly by bowing said first and third regions away from said substrate such that said second region bows toward said substrate to decrease a gap defined between said second region of said mold assembly and said substrate; and

contacting a sub-portion of said liquid with said second region of said mold assembly such that said gas expels from between said substrate and said mold assembly and said liquid fills a volume defined between said mold assembly and substrate.

2. The method as recited in claim 1 wherein the step of altering said shape further comprises a step of creating a first pressure differential between a first chamber defined between a portion of a chuck coupled to said mold assembly and said first region of said mold assembly and a second chamber defined between a portion of said chuck and said second region of said mold assembly and creating a second pressure differential between said second chamber and a third chamber defined between a portion of a chuck coupled to said mold assembly and said third region of said mold assembly.

3. The method as recited in claim 1 wherein the step of altering said shape further comprises a step of subjecting a first chamber defined between a portion of a chuck coupled to said mold assembly and said first region of said mold assembly and an additional chamber defined between a portion of said chuck coupled to said mold assembly and said third region of said mold assembly to a vacuum.

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08/10/2007

Docket No.: P306PC

4. The method as recited in claim 1 wherein the step of contacting said sub-portion further comprises a step of contacting a region of said liquid in superimposition with said second region of said mold assembly.

5. The method as recited in claim 1 further including applying a pressure between said substrate and said mold assembly in superimposition with said first region of said mold assembly to separate said mold assembly from said liquid on said substrate.

6. The method as recited in claim 1 further comprising the step of impinging actinic energy upon said liquid to solidify the same.

7. A method for expelling a gas positioned between a substrate and a mold assembly, said substrate and said mold assembly further having a liquid positioned therebetween, said method comprising the steps of:

positioning said mold assembly and said substrate such that said mold assembly is proximate to said substrate, said mold assembly having a first region, a second region, and a third region, said second region surrounding said first region and said third region surrounding said first and second regions;

altering a shape of said mold assembly by bowing said first and third regions away from said substrate such that said second region bows toward said substrate to decrease a gap defined between said second region of said mold assembly and said substrate, with said first region being bowed by applying a force to a surface of said mold assembly facing said substrate; and

contacting a sub-portion of said liquid with said second region of said mold assembly such that said gas expels from between said substrate and said mold assembly and said liquid fills a volume defined between said mold assembly and substrate.

8. The method as recited in claim 7 wherein the step of altering said shape further comprises a step of creating a first pressure differential between a first chamber defined between a portion of a chuck coupled to said mold assembly and said first region of said mold assembly and a second chamber defined between a

Printed: 08/10/2007

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PCT/US2007/012071

05/18/2007

Docket No.: P306PC

portion of said chuck and said second region of said mold assembly and creating a second pressure differential between said second chamber and a third chamber defined between a portion of a chuck coupled to said mold assembly and said third region of said mold assembly.

9. The method as recited in claim 7 wherein the step of altering said shape further comprises a step of subjecting a first chamber defined between a portion of a chuck coupled to said mold assembly and said first region of said mold assembly and a additional chamber defined between a portion of said chuck coupled to said mold assembly and said third region of said mold assembly to a vacuum.

10. The method as recited in claim 7 wherein the step of contacting said sub-portion further comprises a step of contacting a region of said liquid in superimposition with said second region of said mold assembly.

11 The method as recited in claim 7 further including applying a pressure between said substrate and said mold assembly in superimposition with said first region of said mold assembly to separate said mold assembly from said liquid on said substrate.

12. The method as recited in claim 7 further comprising the step of impinging actinic energy upon said liquid to solidify the same.

Printed: 08/10/2007

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PCT/US2007/012071

Docket No.: P306PC

13. A method for expelling a gas positioned between a substrate and a mold assembly, said substrate and said mold assembly further having a liquid positioned therebetween, said method comprising the steps of:

positioning said mold assembly and said substrate such that said mold assembly is proximate to said substrate, said mold assembly having a first region, a second region, and a third region, said second region surrounding said first region and said third region surrounding said first and second regions;

altering a shape of said substrate such that an area of said substrate in superimposition with said second region of said mold assembly bows towards said mold assembly;

altering a shape of said mold assembly by bowing said first and third regions away from said substrate such that said second region bows toward said substrate to decrease a gap defined between said second region of said mold assembly and said area of said substrate in superimposition therewith; and

contacting a sub-portion of said liquid with said second region of said mold assembly such that said gas expels from between said substrate and said mold assembly and said liquid fills a volume defined between said mold assembly and substrate.

14. The method as recited in claim 13 wherein the step of altering a shape of said substrate further comprises a step of creating a pressure in a first volume defined between a portion of a substrate chuck coupled to said substrate and said area of said substrate.

15. The method as recited in claim 13 wherein the step of altering a shape of said substrate further comprises a step of creating a pressure differential in a first volume defined between a portion of a substrate chuck coupled to said substrate and said area of said substrate and a second volume defined between a portion of said substrate chuck coupled to said substrate and an additional area of said substrate, said additional area surrounding said area.

16. The method as recited in claim 13 wherein the step of altering said shape further comprises a step of creating a first pressure differential between a first

Printed: 08/10/2007

CIM

PCT/US2007/012071

08/10/2007

Docket No.: P306PC

chamber defined between a portion of a chuck coupled to said mold assembly and said first region of said mold assembly and a second chamber defined between a portion of said chuck and said second region of said mold assembly and creating a second pressure differential between said second chamber and a third chamber defined between a portion of a chuck coupled to said mold assembly and said third region of said mold assembly.

17. The method as recited in claim 13 wherein the step of altering said shape further comprises a step of subjecting a first chamber defined between a portion of a chuck coupled to said mold assembly and said first region of said mold assembly and a additional chamber defined between a portion of said chuck coupled to said mold assembly and said third region of said mold assembly to a vacuum.

18. The method as recited in claim 13 wherein the step of contacting said sub-portion further comprises a step of contacting said liquid positioned in superimposition with said area of said substrate with said second region of said mold assembly.

19. The method as recited in claim 13 further including applying a pressure between said substrate and said mold assembly in superimposition with said first region of said mold assembly to separate said mold assembly from said liquid on said substrate.

20. The method as recited in claim 1 further comprising the step of impinging actinic energy upon said liquid to solidify the same.

1/11

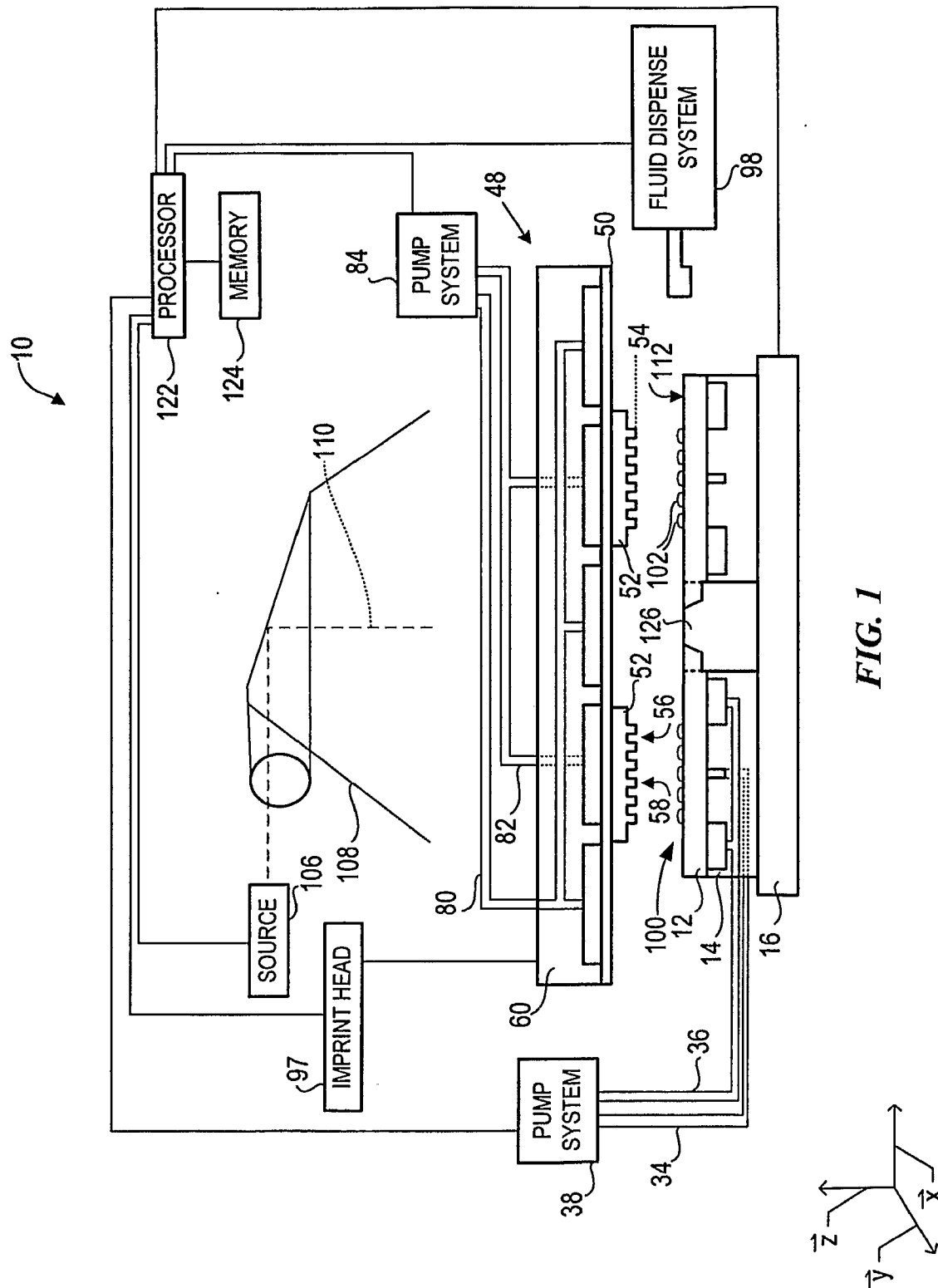


FIG. 1

2/11

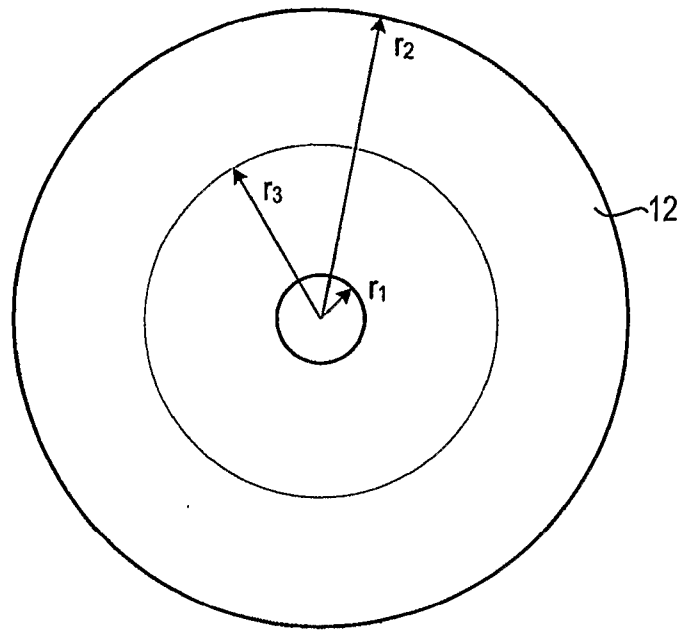


FIG. 2

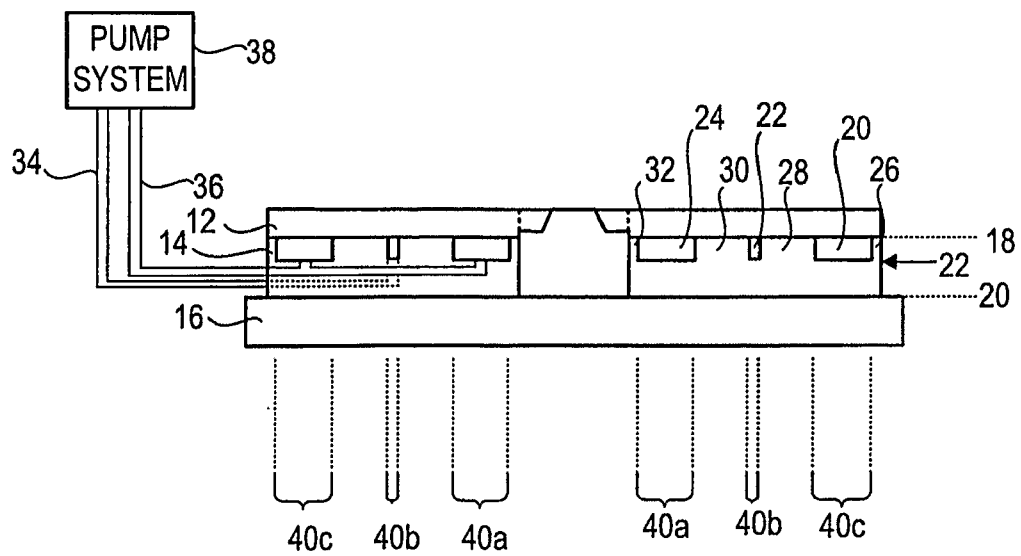


FIG. 3

3/11

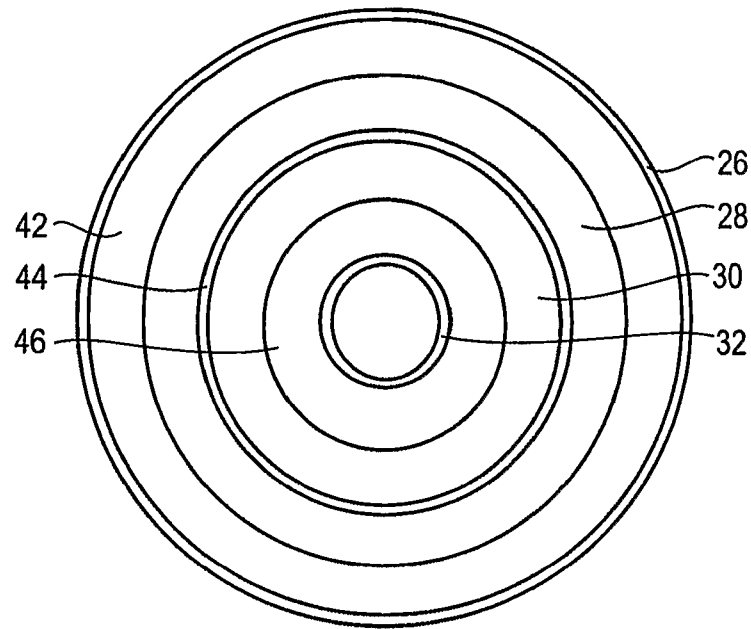


FIG. 4

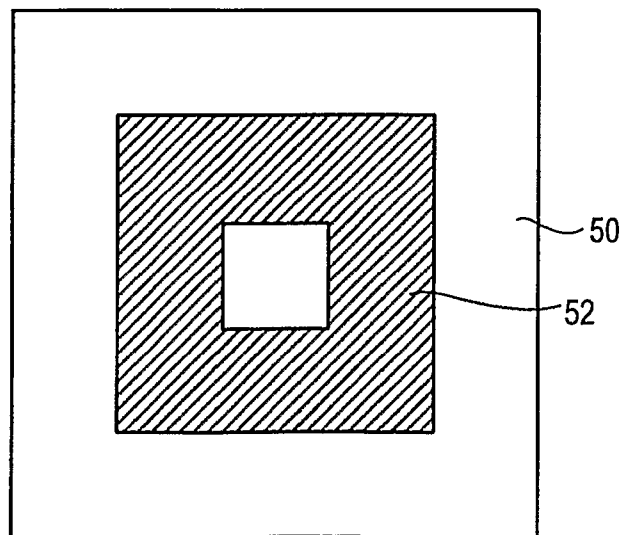


FIG. 5

4/11

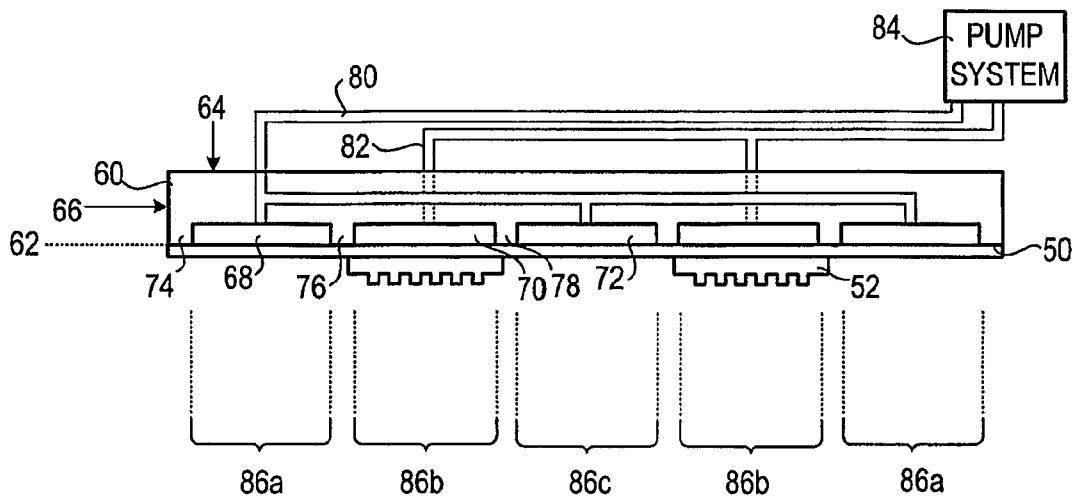


FIG. 6

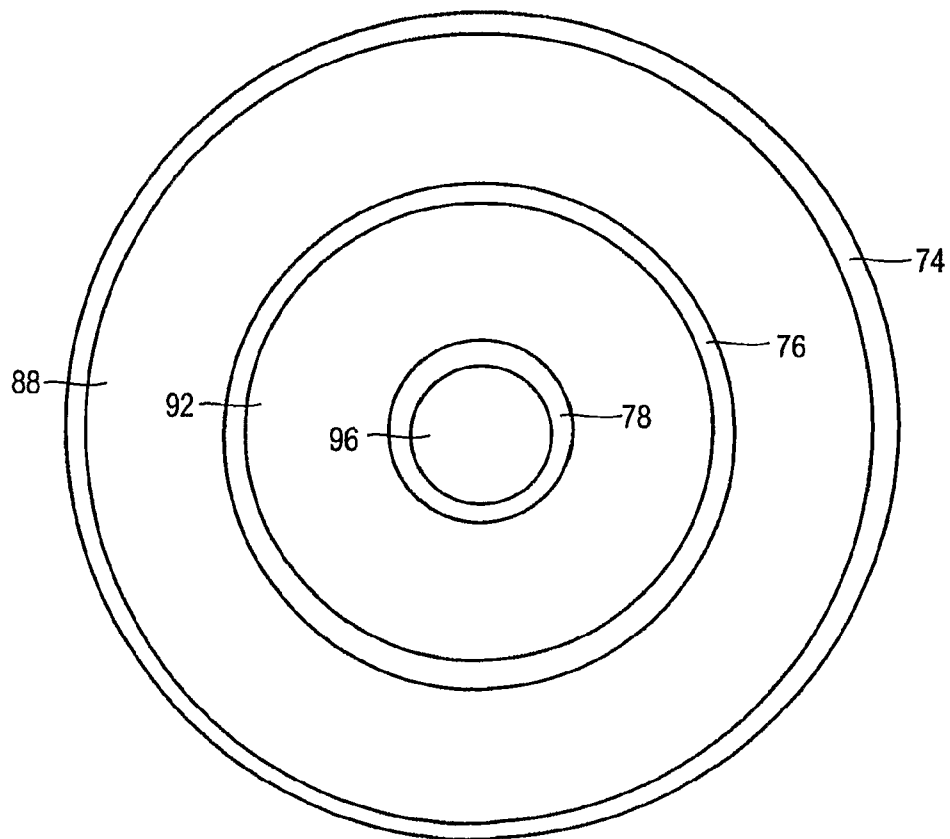


FIG. 7

5/11

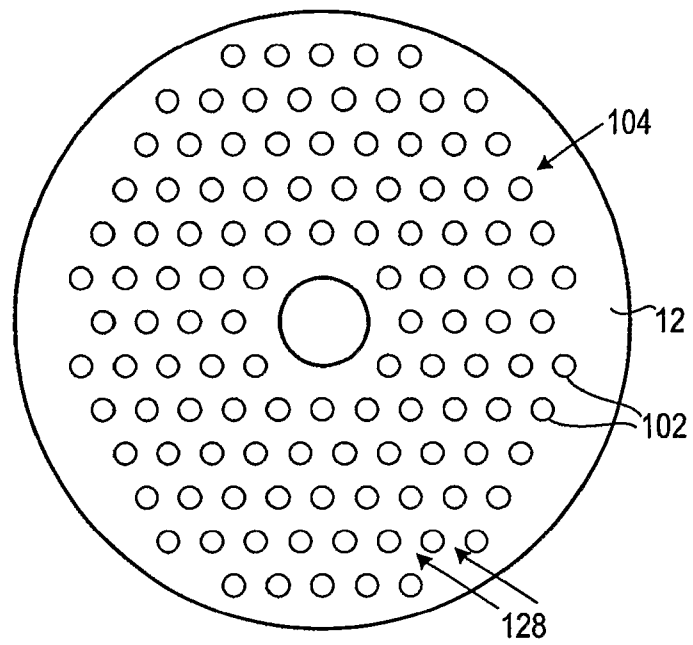


FIG. 8

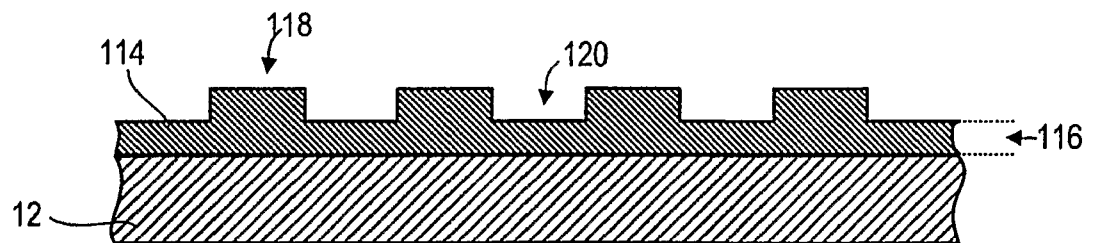


FIG. 9

6/11

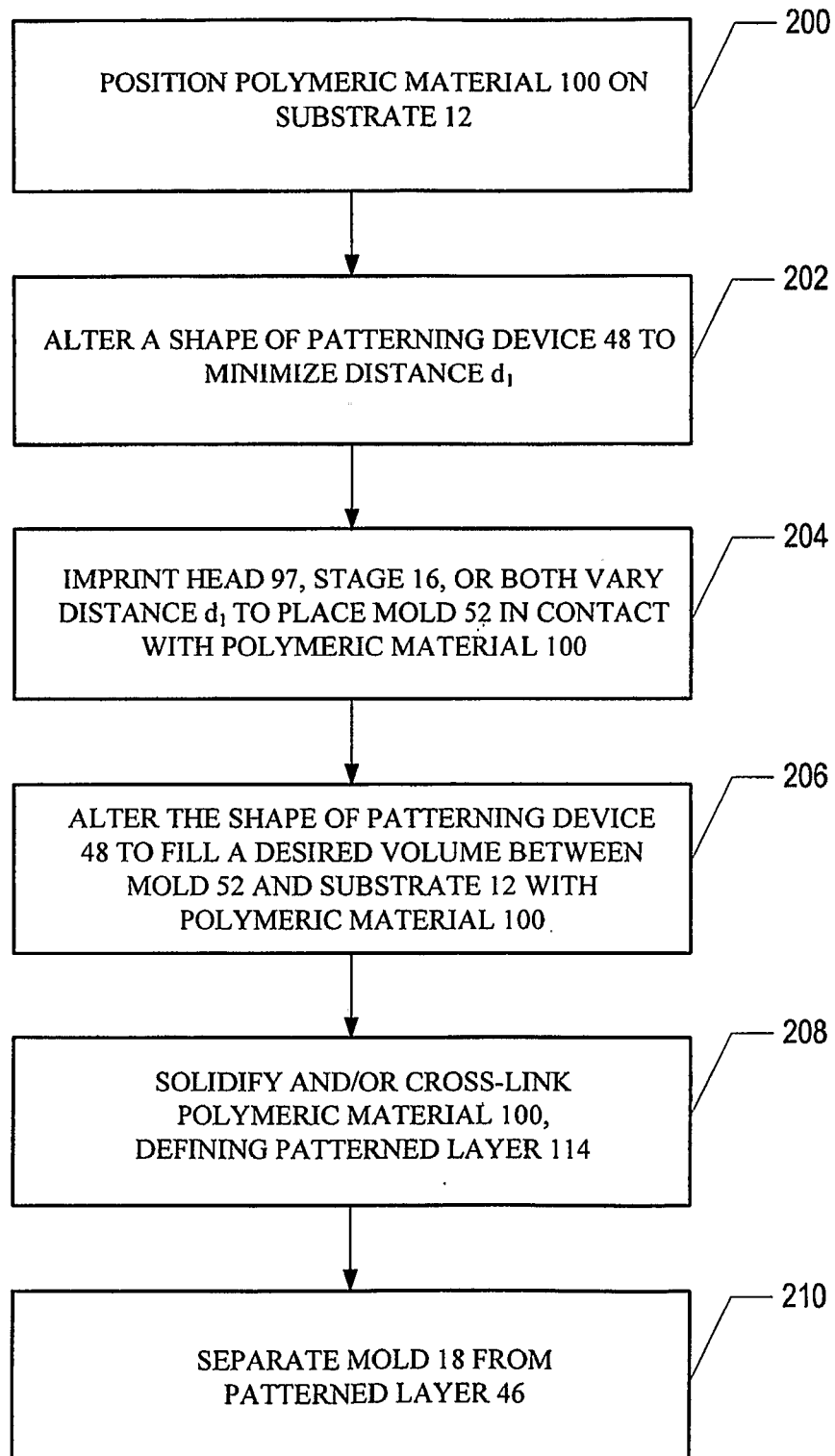
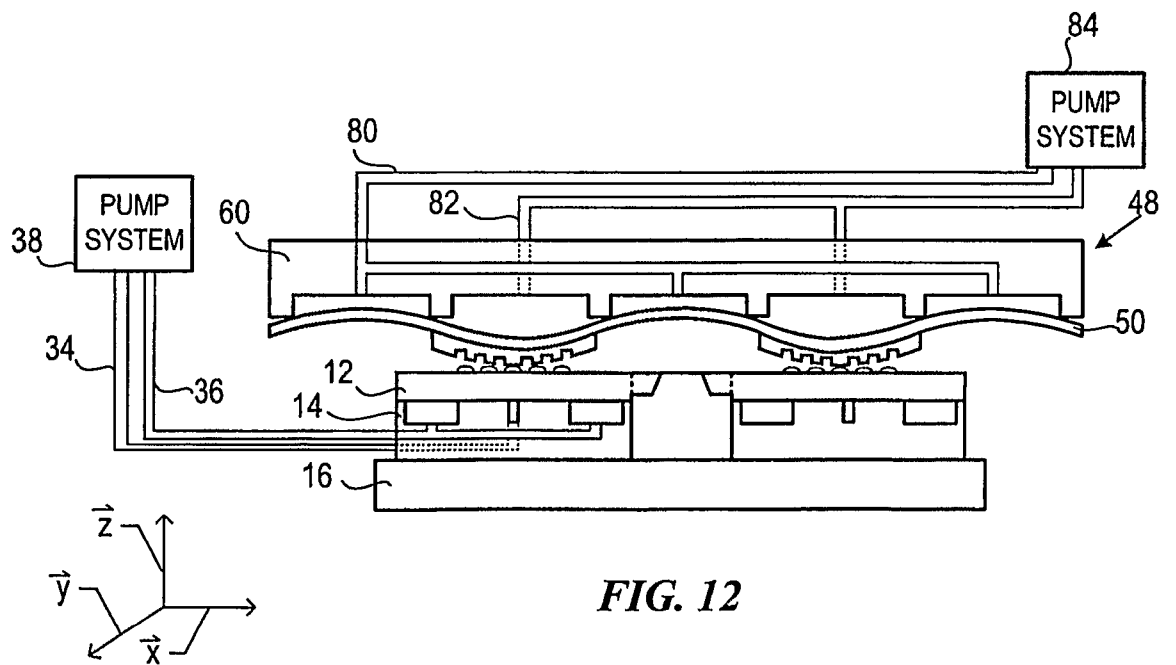
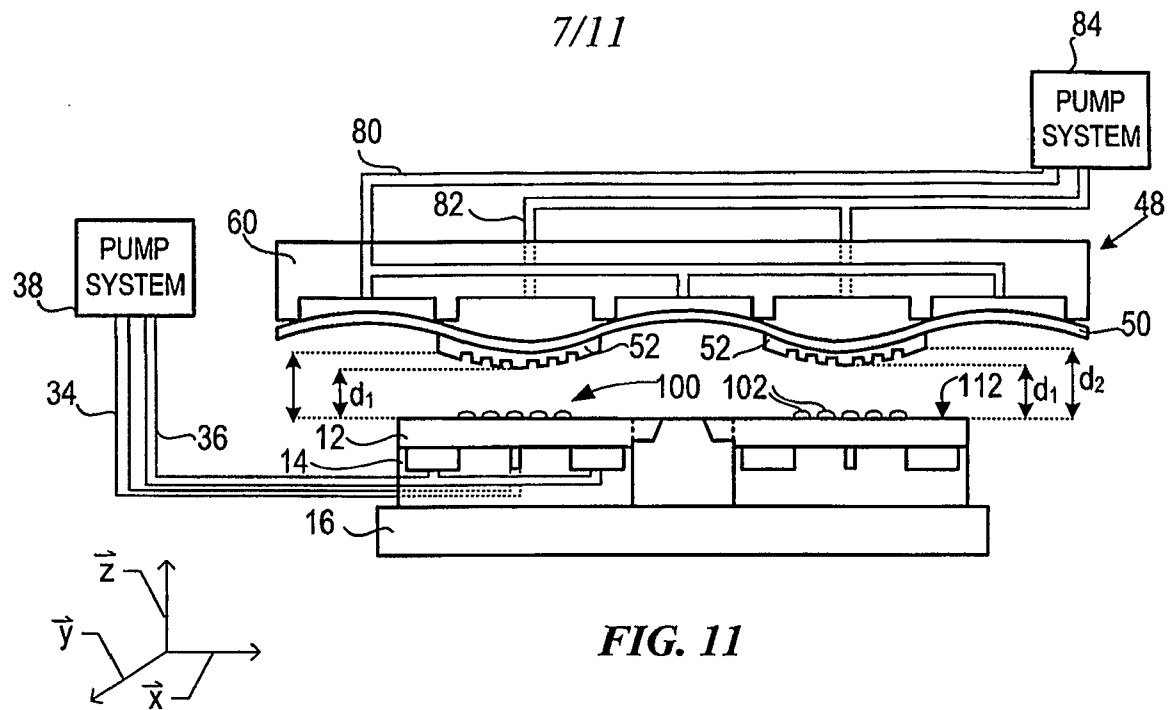


FIG. 10



8/11

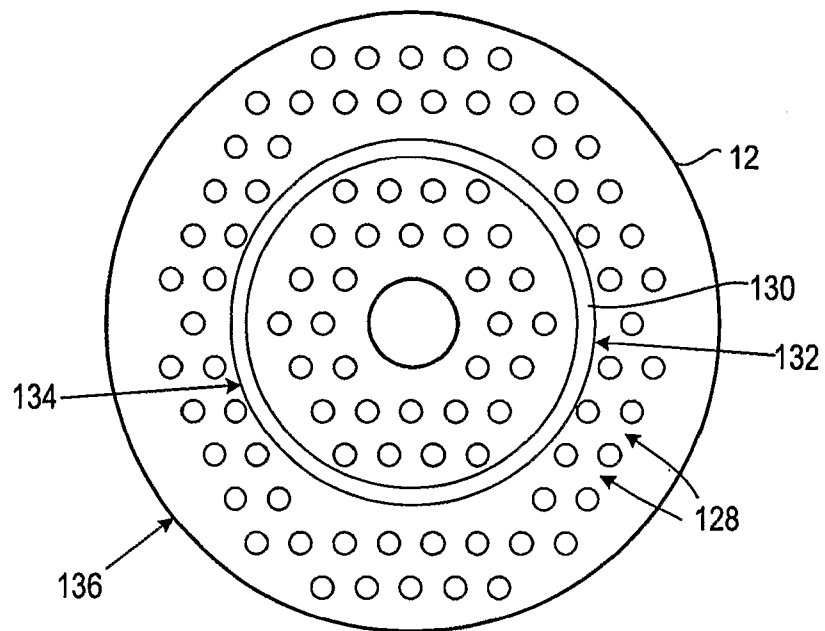


FIG. 13

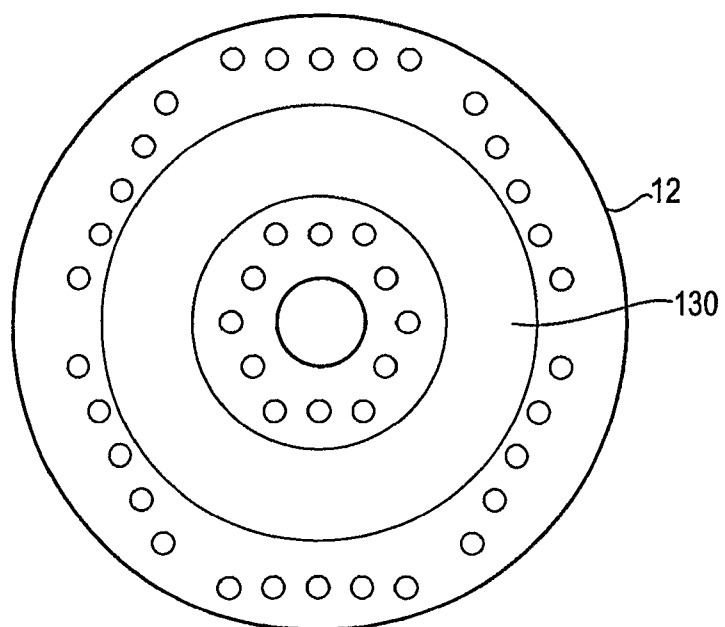


FIG. 14

9/11

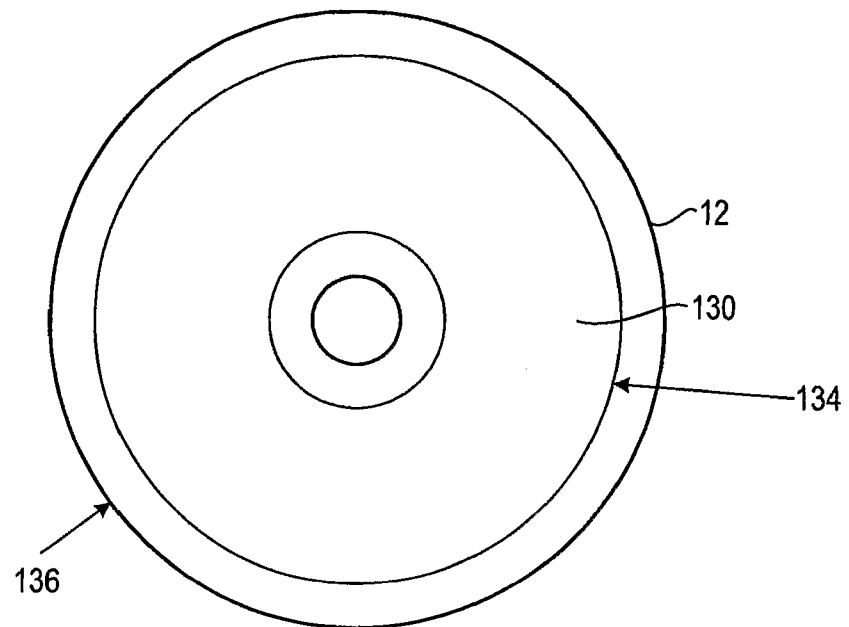


FIG. 15

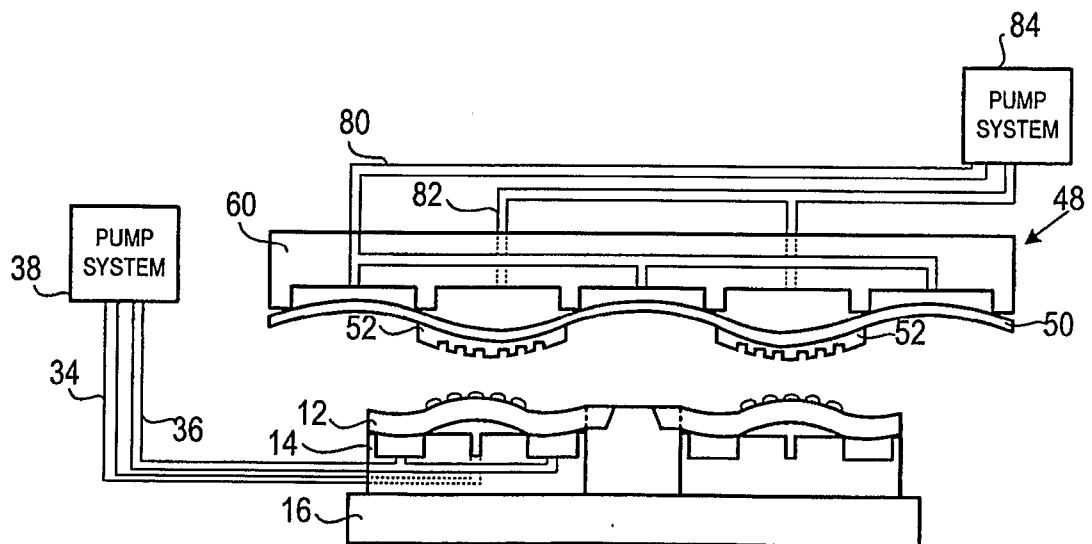
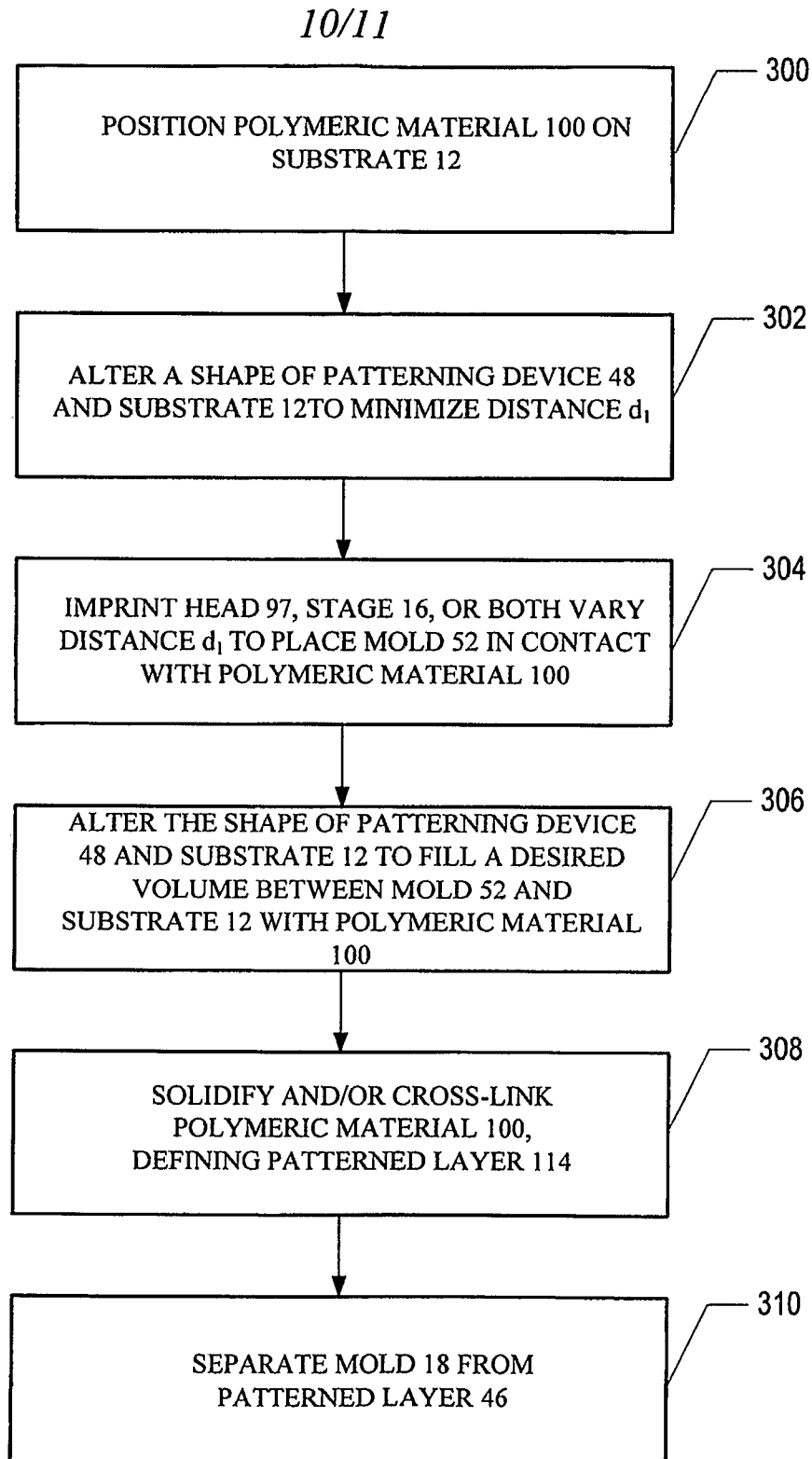


FIG. 17

**FIG. 16**

11/11

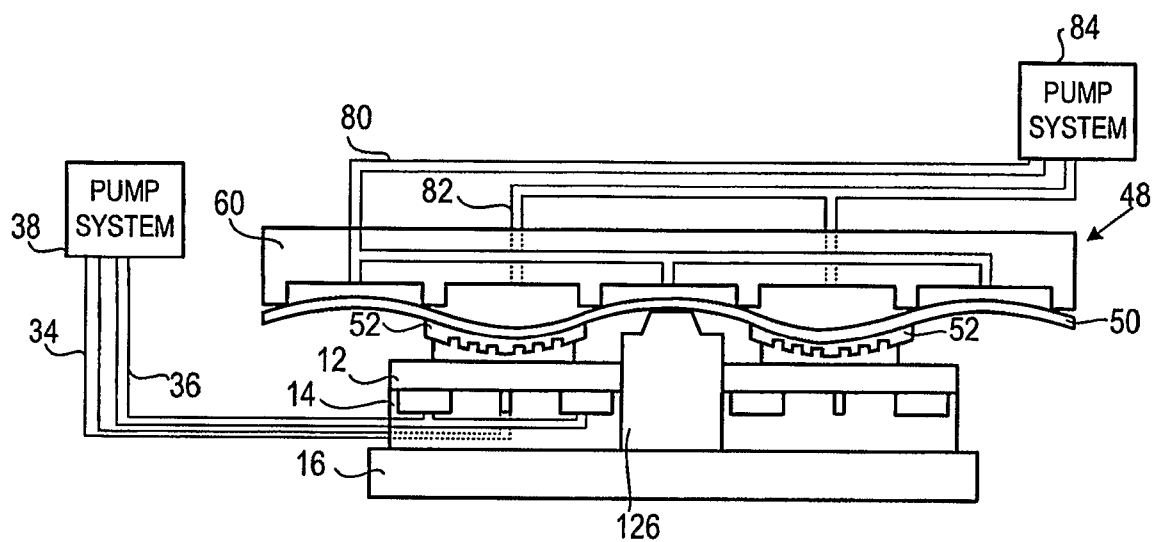


FIG. 18

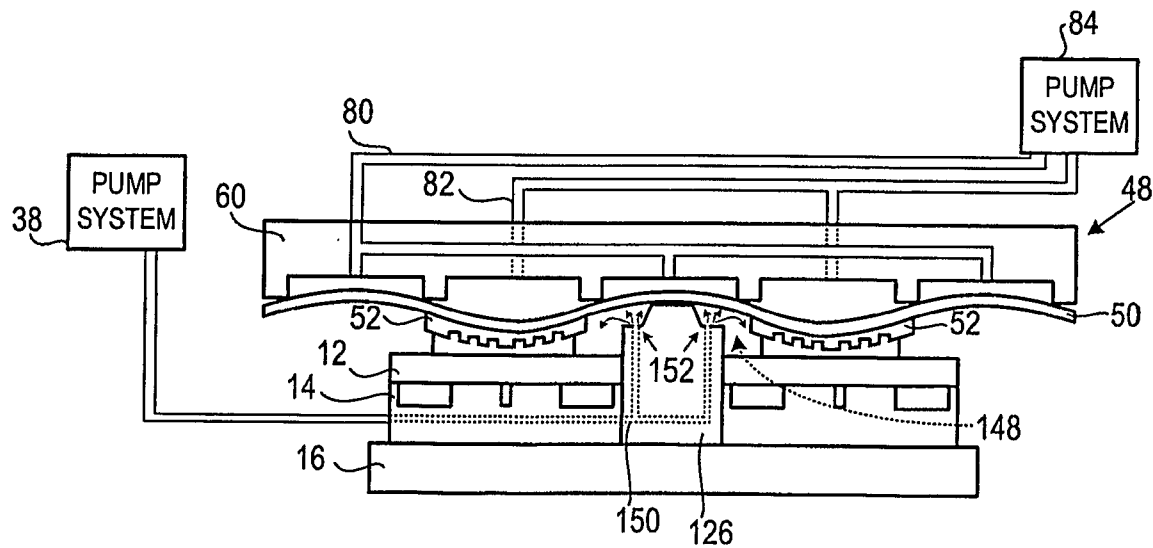


FIG. 19